VIII. CRITICAL NUTRIENT THRESHOLD DETERMINATION AND DEVELOPMENT OF WATER QUALITY TARGETS

VIII.1. ASSESSMENT OF NITROGEN RELATED HABITAT QUALITY

Determination of site-specific nitrogen thresholds for an embayment requires integration of key habitat parameters (infauna and eelgrass), sediment characteristics, and nutrient related water quality information (particularly dissolved oxygen and chlorophyll-a). Additional information on temporal changes within each sub-embayment and its associated watershed nitrogen load further strengthen the analysis. These data were collected to support threshold development for the Nantucket Harbor System by the MEP Team and were discussed in Chapter VII and summarized in Table VIII-1. Nitrogen threshold development builds on this data and links habitat quality to summer water column nitrogen levels from the baseline Water Quality Monitoring Program, conducted by the Town of Nantucket with technical support from the Coastal Systems Program at SMAST and others.

Nantucket Harbor is a complex estuary comprised of a large lagoon, Nantucket Harbor, running parallel to the barrier beach, and smaller enclosed drowned river valley estuary, Polpis Harbor, which is shallow and supports salt marsh along much of its margin. The Nantucket Harbor Estuary formed primarily through the gradual expansion of the barrier beach, Coatue Spit. As an embayment to Nantucket Sound, Nantucket Harbor receives high quality low nutrient flood waters, but by its physical structure supports the enrichment of its basin waters from nitrogen input from the atmosphere and watershed. The morphology of the sub-basins comprising this System, contain deep regions (Quaise, Head of the Harbor) and are enclosed (Polpis Harbor), increasing their susceptibility to the negative impacts from nutrient loading. However, much of the lower Harbor region, between Quaise and the inlet, is well flushed and presently exhibits high habitat quality. Determining the appropriate nitrogen management threshold for the Nantucket Harbor System must take into account both the natural processes and differing sensitivities of its various component sub-basins. In addition, evaluation of the deep regions of Quaise and Head of the Harbor basins must take into account their depositional nature, periodic stratification and low oxygen conditions resulting from either natural or human inputs.

Evaluation of habitat quality must consider the natural structure of each system and the types of eelgrass habitat and infaunal communities that they naturally support. At present, the Nantucket Harbor System is showing variations in nitrogen enrichment among its 4 principal component basins. The inner basins of Head of the Harbor and Polpis Harbor are nitrogen enriched over Quaise and the Town basins. Although the component basins of the Nantucket Harbor System are clearly enriched in nitrogen over the adjacent Nantucket Sound waters, the enrichment is relatively small, generally <0.100 mg L^{-1} (see Chapter VI). The evaluation of habitat quality within each of these 4 basins was based upon the level of nitrogen enrichment, resultant oxygen depletion and chlorophyll enhancement and eelgrass and infaunal indicators relative to ecology of each specific basin.

Like many estuaries where the greatest nitrogen enrichment and impairment is in the inner basins, the overall results of the MEP threshold analysis for Nantucket Harbor indicate infaunal communities in all basins are healthy or relatively healthy. The infaunal communities in this System are generally more productive, diverse and evenly distributed than the other 20 embayments examined to date by the MEP in southeastern Massachusetts. The "impaired" infaunal habitat within the deep regions of the Quaise and Head of Harbor basins appear to derive from basin structure (settling basins) and resultant organic matter deposition and oxygen depletion. It appears that the primary habitat concern for the Nantucket Harbor System relates to eelgrass habitat. Impairment of eelgrass habitat is seen in the present decline in eelgrass coverage in the shallow margin of Head of the Harbor basin and the loss of beds within Polpis Harbor (Table VIII-1). The eelgrass loss in Polpis Harbor (east basin) would indicate a significant to moderate impairment of this sub-system and the declining coverage in Head of the Harbor would classify that basin as moderately impaired. The other regions of the Nantucket Harbor are currently displaying healthy habitats or natural conditions (e.g. deep regions of deep basins). The west basin of Polpis Harbor, which has no historic documentation of supporting eelgrass is therefore classified as supporting relatively healthy (lower reach) and moderately healthy (upper reach) infauna habitat. However, the infaunal communities in Polpis Harbor are consistent with the organically enriched nature of that system, which receives surface water discharge from wetlands and supports salt marsh along its margins.

Eelgrass: Based upon all available data it appears that eelgrass is presently a widespread critical habitat within the Nantucket Harbor System. The present distribution of eelgrass results from recolonization of the Harbor from its loss in the 1930's. A map of eelgrass from the 1940's "shows it to be primarily confined to parts of the Jetties and Horse shed at the Harbor entrance (Kelley 1989). Kelley (1989) concluded that from the 1960's to 1989, "eelgrass distribution has been relatively stable in Nantucket Harbor...". However, it is clear that eelgrass beds have been lost from this System. Both the MassDEP analysis and the direct observations of Kelley in 1989 indicated that there has been measurable eelgrass loss. The primary locations are within Head of the Harbor and East Polpis Harbor. In the 1951 analysis, the east Polpis basin contained an eelgrass bed (Figure VII-12). Kelley observed eelgrass in east Polpis in 1982 but could find no eelgrass in Polpis Harbor in 1989. The other major region experiencing gradual losses, the marginal areas of Head of the Harbor, is supported by both Kelley (1989) and the MassDEP survey data. This larger areal loss appears to be gradual and occurring primarily in the least well flushed areas of this basin (note the counterclockwise circulation). Eelgrass loss has also been noted to the west of Pocomo, which was observed in the 1980 surveys and more recently in changes from 1995-2001. It is important to note that the eelgrass bed loss is both from the shallow area of the upper and mid regions of Head of the Harbor (<8' depth) and from the "deeper" areas (8'-12') in the lower reach and from the shallow east basin of Polpis. The data indicate that that on the order of 1000 acres of eelgrass habitat within the Nantucket Harbor System is impaired.

Macro-algal abundance within the Harbor surveyed in 1994 (Harbor Study 1997) was typical of a relatively healthy environment. Algal cover was highest on the Nantucket Sound side between the points of Coatue (Figure VII-10). The highest concentrations of macro-algae were consistent with the circulation patterns associated with the cusps of land present around the Harbor edge. It also appears that the macro-algal accumulations are not related to terrestrial nitrogen inputs, since the "island" side of the Harbor, which dominates the land based loadings, had lower algal accumulations than Coatue. The absence of macroalgal accumulations and drift algae is consistent with the generally low nitrogen levels throughout this System and the relatively low watershed nitrogen input.

The spatial pattern of bed loss is consistent with the typical pattern of habitat decline related to nitrogen loading. The pattern is for highest nitrogen levels to be found within the innermost basins, with concentrations declining moving toward the tidal inlet. This pattern is also seen in the other nutrient related habitat quality parameters, like chlorophyll, turbidity, oxygen depletion, etc. The consequence is that eelgrass bed decline typically follows a pattern of initial loss in the innermost basins and from the deeper waters. The temporal pattern is a “retreat” of beds toward the region of the tidal inlet. This appears to be the pattern of retreat observed within Head of the Harbor and Polpis Harbor (east basin). Although Nantucket Harbor generally supports healthy infaunal habitat (tolerant of higher levels of enrichment), it appears to have reached sufficient nutrient enriched to impair its eelgrass habitat. However, it appears that this System is just over its nitrogen assimilative capacity (nitrogen threshold), as it still supports significant eelgrass habitat. Being just at or over its threshold makes it likely that if nitrogen loading were to decrease, eelgrass could be restored.

Table VIII-1. Summary of Nutrient Related Habitat Health within the Nantucket Harbor Estuarine System on Nantucket Island within the Town of Nantucket, MA., based upon assessment data presented in Chapter VII. The bilobate Polpis Harbor is an enclosed sub-system tributary to the Quaise basin.

	Nantucket Harbor Estuarine System				
Health Indicator	**Head of Harbor**	**Quaise**	**Town Basin**	**Polpis Harbor**	
				East	**West**
Dissolved Oxygen	H[2]/MI[1]	H[2]/MI[1]	H[2]	H/MI[3]	H/MI[3]
Chlorophyll	H[6,7]	H[6,7]	H[6,7]	H[6,7]	H[6,7]
Macroalgae	--[4]	--[4]	--[4]	--[4]	--[4]
Eelgrass	MI[13]	H	H	SI[12]	--[11]
Infaunal Animals	H[8]/MI[9]	H[8]/MI[9]	H[5]	H/MI[10]	H/MI[10]
Overall:	**H[8]/MI[9]**	**H**	**H**	**MI[14]**	**H/MI**

1 – in the deep basins oxygen depletions periodically 4-5 mg/L., generally >5 mg/L.
2 -- in the large moderate/shallow areas accounting for most of the basin region, oxygen levels generally > 6 mg/L with occasional depletions to between 6-5 mg/L
3 – oxygen depletions periodically to 4.5-6 mg/L, generally above 6 mg/L.
4 – very sparse or absence of drift algae based upon Nantucket Harbor Study Survey
5 – generally high diversity, high numbers, eveness generally ≥0.7.
6 -- based upon limited monitoring grab sample data.
7 -- secchi depth generally to bottom in Polpis, averaging 2.3-2.6 in main Harbor basins
8 – extensive shallow areas generally moderate-high numbers of individuals and species, eveness generally high.
9 -- deep region of basin diminished numbers of individuals and species, with some organic matter enrichment indicators.
10 -- moderate numbers of species and individuals, but high diversity and eveness, enrichment indicator - *Mediomastus* dominant.
11 – no evidence this basin is supportive of eelgrass.
12 -- historical eelgrass beds lost
13 -- some gradual decline in distribution of historical eelgrass beds
14 -- based upon eelgrass loss

H = healthy habitat conditions; MI = Moderate Impairment; SI = Significant Impairment; SD = Severe Degradation; -- = not applicable to this estuarine reach

It is important to note that the nitrogen levels throughout the Nantucket Harbor System remain relatively low, consistent with the observed oxygen conditions, lack of macroalgae and chlorophyll a levels. However, due to the water depth in the Harbor, it is possible that vertical and horizontal mixing rates appear to have resulted in a decline in eelgrass bed coverage from the deeper areas and more enclosed basin areas. While eelgrass was recently within Polpis Harbor, it is presently absent at a tidally average total nitrogen (TN) level of 0.361 mg N L-1. Loss at this nitrogen level is consistent with observed losses at generally similar depths in West Falmouth Harbor above 0.350 mg N L^{-1} and observed losses in Phinneys Harbor at 0.36 mg N L^{-1}. However, given the shallower depth of Polpis Harbor, it is likely that it is just slightly above its threshold level at present, since shallower waters can generally support eelgrass at slightly higher nitrogen levels than deeper waters. Similarly, tidally averaged levels in the lower reach of Head of the Harbor (0.340-0.353) and mid and upper reach (0.390 mg N L-1) also suggest that the recent bed losses are from a recent exceedance of the supportive nitrogen threshold. The data indicate that eelgrass habitat within the inner basins of the Nantucket Harbor System are impaired, being at or beyond their ability to assimilate more nitrogen without further loss of eelgrass beds. The Head of the Harbor basin is clearly moderately impaired for eelgrass, due to the documented loss of eelgrass coverage, but the continued presence of eelgrass in the marginal areas and in the lower reach would indicate the possibility for restoration of these marginal beds with future decreases in nitrogen load to this basin. The east basin of Polpis Harbor is presently significantly impaired, as it supported a significant eelgrass bed in 1951 and some eelgrass in 1982 and 1989, but no longer supports eelgrass. The west basin of Polpis Harbor does not have a record of eelgrass. Both Polpis Basins support infaunal communities commensurate with the nature of the enclosed basins and their association with wetlands. Therefore, it is clear that resource management should focus on eelgrass habitat and on preventing further increase in nitrogen levels and as possible some reduction over current loading levels.

Water Quality: Dissolved oxygen levels near atmospheric equilibration are important for maintaining healthy animal and plant communities. Short-duration oxygen depletions can significantly affect communities even if these excursions are relatively rare on an annual basis. For example, for the Chesapeake Bay it was determined that restoration of nutrient degraded habitat requires that instantaneous oxygen levels not drop below 3.8 mg L^{-1}.

Within the highly flushed and generally well mixed waters of the lower basins of Nantucket Harbor, bottom waters were well oxygenated (>6mg L^{-1}). The few excursions below 6 mg L^{-1} were isolated events, rather than a prolonged depletion such as generally associated with a phytoplankton bloom. However, these variations were small and overall the oxygen conditions are consistent with the observations of healthy infaunal and eelgrass communities. While Polpis Harbor also exhibited well oxygenated conditions, larger diurnal variations were recorded than in the outer basins. The higher diurnal fluctuations indicate waters supporting higher phytoplankton biomass. The lack of a low oxygen event is likely the result of the lack of watercolumn stratification within this shallow system.

Quaise basin showed both significant diurnal oxygen fluctuations and an overall oxygen decline, although not to levels of high stress. There was a single "event" of a few days when each night oxygen levels reached 4 mg/L, but returned to ~5 mg L^{-1} each following day. Since the meter was located deeper within the basin (~6 m), oxygen levels throughout most of the basin area were almost certainly higher given their shallower depths, only in the "deep hole" was oxygen depletion likely greater. Assessing oxygen conditions within the Quaise basin indicates generally non-stressful oxygen levels, except for the deep basin. However, it is likely that the presence of the deep hole (~30') creates a geomorphological (natural) cause of the low dissolved oxygen, as it creates a depositional area and is susceptible to periodic watercolumn stratification. The depositional nature of the basin results in large accumulations of eelgrass detritus in the late fall and early spring. It is likely that a major function of these periodically deposited mats is to smother the infaunal communities at the bottom of the "hole", as the surficial sediments beneath them were observed to lack a surface oxygenated layer with hydrogen sulfide reaching the sediment/water interface. There is evidence that the mats are transitory and do not occur each year. Their deposition is likely mediated by water circulation which is both tidally and storm driven in this system. It should be noted that these large deposition events are not related to nitrogen loading of the Harbor System.

Similarly, Head of the Harbor showed generally high oxygen levels. As in the Quaise basin, the meter was deeper in the basin and observed oxygen depletions were greater than experienced by bottom waters throughout most of the basin area. The oxygen conditions are consistent with the observed distribution of habitat quality throughout the Harbor System, with the deep waters showing oxygen depletion, but with oxygen levels generally supportive of a high habitat quality for infauna. However, since the system does show oxygen levels less than full atmospheric saturation, additional organic matter loads, (e.g. through nitrogen inputs) will likely increase the magnitude and frequency of the oxygen declines, again indicating a system at or just beyond its nitrogen assimilative capacity (nitrogen threshold).

The oxygen records from the moored instrumentation are consistent with the results from the periodic grab samples by the water quality monitoring programs. While grab samples are not necessarily a good indication of the degree of oxygen depletion in embayment waters, given the potential temporal variation, the data can be used if there are sufficient numbers of sampling dates. Given the 81 sampling dates in Nantucket Harbor from 1988-2005, an analysis was conducted by the MEP Technical Team. This analysis confirms the results of the mooring data. At all stations and dates throughout the Nantucket Harbor System, only a single sample was found to be <4 mg L^{-1} and that was from the deep water in the Head of the Harbor basin (7 m, 3.68 mg L^{-1}) in 1993. The next lowest value recorded in the System was 4.4 mg L^{-1}. In Quaise and the Town there were only 5 and 8 samples <6 mg L^{-1}, with the only 1 sample < 5 mg L-1 (4.81 mg L^{-1}). Polpis Harbor showed slightly more frequent, but still only moderate depletions, with the in the East and West basins having 4 and 3 dates between 4.4-5.99 mg L-1 and a total of 12 dates <6 mg L^{-1}. These data support the contention that except in the deep holes of the main Harbor, oxygen depletion is generally only short term and moderate, with the overall summer conditions showing oxygen levels supportive of healthy to moderately healthy infaunal habitat.

Overall, oxygen within the Harbor bottom waters appears to remain at ecologically healthy levels, except for periodic oxygen depletion within the deepest portions of the Quaise and Wauwinet basins. However, as there were some oxygen depletions below 5 mg L-1 in the main basins (although infrequent), it appears that the system is at or just beyond it ability to assimilate additional nitrogen/organic matter. Increasing organic matter deposition either through direct inputs or via enhanced production from increased nutrient loading is nearly certain to increase the level of oxygen related ecological stress. Decreasing organic matter deposition, either through lowered production or increased export should result in improvements in benthic habitat within these basins.

Infaunal Communities: The infaunal data (MEP and Harbor Study surveys) indicated an overall system supporting generally healthy infaunal habitat relative to the ecosystem types represented. Evaluation of infaunal habitat quality considered the natural structure of each system relative to the type of infaunal communities that they support.

The infaunal data clearly show that the lower basins and shallower areas (<12') of the main Harbor basins generally support high quality infaunal habitat. The lowermost basin (Town) exhibited a dense, highly diverse and relatively evenly distributed community, with some variation. The shallower margins of both Quaise and Head of the Harbor were only slightly less diverse than areas nearer the tidal inlet, but were clearly of high quality. This is further evidenced by the growth of epibenthic scallops in these areas. Within the main Harbor basins, only the deep "holes" showed reduced numbers of species and individuals and organic enrichment indicators. This indication of moderate to poor habitat in these deep regions is consistent with the previous analysis and supported by the observed accumulations of organic detritus in these natural depositional areas. It is unlikely that management of nitrogen loading will be able to create significant improvement within these deep basin regions and it is likely that these areas have been "stressed" by natural processes for a long time.

Both the MEP and Harbor Study surveys found Polpis Harbor to be supportive of both moderate to large numbers of species and individuals of diverse and even distribution. However, both studies found the habitat in both the east and west basins to be dominated by productive communities dominated by organic matter enrichment indicators, presently *Mediomastus*. It is likely that this community is structured by the enclosed nature of Polpis Harbor and its associated wetland, which results in enrichment of nitrogen and organic matter and deposition to the sediments. However, the benthic community is clearly productive and diverse and therefore, for its local environment appears healthy.

Overall, the MEP system-wide survey found higher numbers of species and individuals in communities that were generally more diverse and evenly distributed than the other 20 embayments examined to day by the MEP in southeastern Massachusetts. This is consistent with the relatively low tidally averaged nitrogen levels within the system, <0.40 mg N L-1 and generally 0.285-0.361 mg N L^{-1}. It should be noted that this upper limit of the Nantucket Harbor System tidally averaged nitrogen level compares well to the levels found to support healthy infauna in West Falmouth Harbor (main basin) of 0.38 mg N L^{-1}, the Phinneys Harbor System of <0.42 mg N L^{-1} and in enclosed basins along Nantucket Sound (e.g. Perch Pond, Bournes Pond, Popponesset Bay) where levels <0.5 mg N L^{-1} were found to be supportive of healthy infaunal habitat. It appears that the primary habitat concern for the Nantucket Harbor System is the present decline in eelgrass coverage.

VIII.2. THRESHOLD NITROGEN CONCENTRATIONS

The approach for determining nitrogen loading rates, which will maintain acceptable habitat quality throughout an embayment system, is to first identify a sentinel location within the embayment and second to determine the nitrogen concentration within the water column which will restore that location to the desired habitat quality. The sentinel location is selected such that the restoration of that one site will necessarily bring the other regions of the system to acceptable habitat quality levels. Once the sentinel site and its target nitrogen level are determined, the Linked Watershed-Embayment Model is used to sequentially adjust nitrogen loads until the targeted nitrogen concentration is achieved.

Determination of the critical nitrogen threshold for maintaining high quality habitat within the Nantucket Harbor Estuarine System is based primarily upon the nutrient and oxygen levels, temporal trends in eelgrass distribution and current benthic community indicators. Given the database it is possible to develop a site-specific threshold, which is a refinement upon general threshold analysis frequently employed.

The Nantucket Harbor System is presently supportive of infaunal habitat throughout its main basins, but is clearly impaired by nitrogen enrichment within the Head of the Harbor basin and in the eastern basin of Polpis Harbor, based upon eelgrass losses.. Given the documented importance of eelgrass habitat to these basins and the demonstrable loss of eelgrass that were supported, eelgrass restoration in these basins was set as the primary nitrogen management goal for the overall System. Due to the semi-isolated nature of Polpis Harbor from Nantucket Harbor, it is necessary to establish 2 sentinel stations for eelgrass, one in the Head of the Harbor and one in the east basin of Polpis Harbor (e.g. where eelgrass had been observed in 1951-1989).

Infaunal habitat is also important within the Nantucket Harbor System. However, under present nitrogen loading and watercolumn levels, infaunal habitats are generally healthy, with the exception of the deep regions of the deep basins, which are structurally "impaired". The System supports generally higher numbers of species and individuals in communities that are generally more diverse and evenly distributed than the other 20 embayments examined to date by the MEP in southeastern Massachusetts. These healthy infaunal habitats are consistent with the relatively low tidally averaged nitrogen levels throughout the Nantucket Harbor System, <0.40 mg N L-1 and generally 0.285-0.361 mg N L^{-1}. It should be noted that this upper limit of the Nantucket Harbor System tidally averaged nitrogen level, compares well to the levels found to support healthy infauna in West Falmouth Harbor (main basin) of 0.38 mg N L^{-1}, the Phinneys Harbor System of <0.42 mg N L^{-1} and in enclosed basins along Nantucket Sound (e.g. Perch Pond, Bournes Pond, Popponesset Bay) where levels <0.5 mg N L^{-1} were found to be supportive of healthy infaunal habitat. Therefore no secondary infaunal planning nitrogen thresholds were developed for this estuary.

The tidally averaged total nitrogen threshold to support eelgrass at documented historical levels throughout the Nantucket Harbor System are based upon the water quality monitoring and modeling data and the observed temporal and spatial changes in eelgrass distribution within Head of the Harbor and Polpis Harbor east basin. In addition, evaluation of the nitrogen loading under present conditions and with no anthropogenic watershed inputs (Section VI) provides insight into the temporal effects of watershed nitrogen loading versus the much larger atmospheric source to this estuary.

It is important to note that the nitrogen levels throughout the Nantucket Harbor System remain relatively low, consistent with the oxygen conditions, lack of macroalgae and chlorophyll a levels. However, the water depth of the Harbor and possibly vertical and horizontal mixing rates appear to have resulted in a decline in eelgrass bed coverage from the deeper areas and more enclosed basin areas. While eelgrass was only recently lost from the east basin of Polpis Harbor, it is presently absent at a tidally average total nitrogen (TN) level of 0.361 mg N L-1. Loss at this nitrogen level is consistent with observed losses in West Falmouth Harbor above 0.350 mg N L-1, however, given the shallower depth of Polpis Harbor, it is likely that it is just slightly above its threshold level at present. Similarly, tidally averaged levels in the lower reach of Head of the Harbor (0.340-0.353) and mid and upper reach (0.390 mg N L-1) also suggest that the recent bed losses are from a recent exceedance of the supportive nitrogen threshold. Given all of the factors discussed above and the similarity of Head of the Harbor to conditions in West Falmouth and Phinneys Harbors and its present nitrogen levels, a nitrogen threshold of 0.350 mg N L-1 was determined to be supportive of eelgrass habitat in this system. This threshold should also support eelgrass in the shallower regions as well. As the east basin of

Polpis Harbor has only recently lost its eelgrass and is presently 0.361 mg N L-1, but has shallower waters than Head of the Harbor, only a slight reduction over present levels appears to be needed to support eelgrass habitat. Clearly the threshold must be lower than the present 0.361 mg N L^{-1} and higher than that for Head of the Harbor (0.350 mg N L^{-1}). Therefore, a threshold of 0.355 mg N L-1 was set for the sentinel station in Polpis Harbor. It should be noted that the Polpis Harbor threshold is well constrained by the available data, but is at the limits of the sensitivity of the MEP approach. Therefore concerning eelgrass, management should focus on no net increase in nitrogen loading to the Harbor System and as possible some reduction over current loading levels to Polpis Harbor and Head of the Harbor basins. The nitrogen loads associated with the threshold concentration at the sentinel location are discussed in Section VIII.3, below.

VIII.3 DEVELOPMENT OF TARGET NITROGEN LOADS

The nitrogen thresholds developed in the previous section were used to determine the amount of total nitrogen mass loading reduction required for restoration of eelgrass and infaunal habitats in the Nantucket Harbor system. Tidally averaged total nitrogen thresholds derived in Section VIII.1 were used to adjust the calibrated constituent transport model developed in Section VI. Because the Harbor system is just slightly over the threshold, and because extensive sewering is already in place in the Town watershed, two threshold scenarios where modeled in order to demonstrate the level of effort required to achieve the threshold concentrations set for this system at the 2 sentinel stations for eelgrass in the Head of the Harbor and Polpis Harbor (east basin). Two sentinel stations are needed for this System due to the semi-isolated nature of Polpis Harbor from Nantucket Harbor. A comparison between present septic and total watershed loading and the loadings for the two modeled threshold scenarios is provided in Tables VIII-2 and VIII-3.

The first threshold scenario (scenario “A”) considers the water quality improvements that are possible with 100% of the present septic watershed load from the town watershed, and also 80% removal of the total anthropogenic watershed loads (septic, fertilizer and non-pervious surfaces) from the remaining three Harbor watersheds. The intent of this scenario is to simulate the likely loading condition of the Harbor approximately 50 years before present, at a time when eelgrass is documented to have existed in Polpis Harbor.

The second threshold scenario (scenario “B”) considers water quality improvements that are possible with the removal of 100% of septic loads from all four of the Harbor Watersheds. Though this is not a likely solution, this scenario does indicate the maximum possible benefit from septic removal alone.

These scenarios represent only two of a suite of potential reduction approaches that need to be evaluated by the community. The model results of these scenarios aid in establishing the general degree and spatial pattern of reduction that is possible toward the goal of restoration of this system. The modeling results provide one manner of achieving the selected threshold level for the sentinel sites within the estuarine system; these specific examples do not represent the only method for achieving this goal. However, the thresholds analysis provides general guidelines needed for the nitrogen management of this embayment.

Tables VIII-4 and VIII-5 show the breakdown of threshold sub-embayment and surface water loads used for total nitrogen modeling. In Tables VIII-4 and VIII-5, loading rates are shown in kilograms per day, since benthic loading varies throughout the year and the values shown represent ‘worst-case’ summertime conditions. The benthic flux for these scenarios is reduced from existing conditions based on the load reduction and the observed particulate organic nitrogen (PON) concentrations within each sub-embayment relative to background concentrations in Nantucket Sound, as discussed in Section VI.

Table VIII-2. Comparison of sub-embayment watershed ***septic loads*** (attenuated) used for modeling of present and threshold loading scenarios of the Nantucket Harbor system. These loads do not include direct atmospheric deposition (onto the sub-embayment surface), benthic flux, runoff, or fertilizer loading terms.

sub-embayment	present septic load (kg/day)	threshold "A" septic load (kg/day)	Threshold "A" septic load % change	threshold "B" septic load (kg/day)	Threshold "B" septic load % change
Head of the Harbor	0.705	0.141	-80.0%	0.000	-100.0%
Polpis Harbor	0.435	0.087	-80.0%	0.000	-100.0%
Quaise Basin	0.392	0.078	-80.0%	0.000	-100.0%
Town Basin	5.194	0.000	-100.0%	0.000	-100.0%
System Total	6.726	0.306	-95.4%	0.000	-100.0%

Table VIII-3. Comparison of sub-embayment ***total watershed loads*** (including septic, runoff, and fertilizer) used for modeling of present and threshold loading scenarios of the Nantucket Harbor system. These loads do not include direct atmospheric deposition (onto the sub-embayment surface) or benthic flux loading terms.

sub-embayment	present load (kg/day)	threshold "A" load (kg/day)	threshold "A" % change	threshold "B" load (kg/day)	threshold "B" % change
Head of the Harbor	1.858	0.792	-57.4%	1.153	-37.9%
Polpis Harbor	3.529	2.175	-38.4%	3.093	-12.3%
Quaise Basin	2.123	1.140	-46.3%	1.732	-18.5%
Town Basin	15.901	10.707	-32.7%	10.707	-32.7%
System Total	23.411	14.814	-36.7%	16.685	-28.7%

Table VIII-4. Threshold "A" sub-embayment loads used for total nitrogen modeling of the Nantucket Harbor system, with total watershed N loads, atmospheric N loads, and benthic flux

sub-embayment	watershed load (kg/day)	direct atmospheric deposition (kg/day)	benthic flux net (kg/day)
Head of the Harbor	0.792	22.239	-16.795
Polpis Harbor	2.175	2.190	26.450
Quaise Basin	1.140	20.126	43.010
Town Basin	10.707	13.888	-2.892
System Total	14.814	58.443	49.772

Table VIII-5. Threshold "B" sub-embayment loads used for total nitrogen modeling of the Nantucket Harbor system, with total watershed N loads, atmospheric N loads, and benthic flux

sub-embayment	watershed load (kg/day)	direct atmospheric deposition (kg/day)	benthic flux net (kg/day)
Head of the Harbor	1.153	22.239	-17.182
Polpis Harbor	3.093	2.190	26.655
Quaise Basin	1.732	20.126	42.885
Town Basin	10.707	13.888	-2.892
System Total	16.685	58.443	49.466

Modeled TN concentrations for present loading conditions and the two modeled scenarios are presented in Table VIII-6. Contour plots of model output for the two separate scenarios are show in Figures VIII-1 and VIII-2. The model results show that because N loading to the Nantucket Harbor system is dominated by atmospheric deposition and benthic flux, large percentage reductions in the anthropogenic N sources to the Harbor result only in small changes to TN concentrations in the system. For example, a -36.7% reduction in the total system watershed load in scenario "A" results in only a -1.5% reduction in TN concentrations at the sentinel station in East Polpis Harbor. These small changes in TN are necessary to re-establish eelgrass habitat in areas where it was found circa 1950.

Table VIII-6. Comparison of model average total N concentrations from present loading and the threshold scenario, with percent change, for the Nantucket Harbor system. Loads are based on atmospheric deposition and a scaled N benthic flux (scaled from present conditions). The threshold stations are shown in bold print (Sta. 2.1 is SMAST 2A, Sta. 4 is Town 6 and SMAST 4, see Table VI-1).

Sub-Embayment	monitoring station	present (mg/L)	threshold "A" (mg/L)	threshold "A" % change	Threshold "B" (mg/L)	threshold "B" % change
Head of the Harbor - Upper	2	0.397	0.392	-1.3%	0.393	-1.0%
Head of the Harbor - Mid	2.2	0.390	0.385	-1.3%	0.386	-1.0%
Head of the Harbor - Lower	**2.1**	**0.353**	**0.349**	**-1.1%**	**0.350**	**-0.8%**
Pocomo Head	3	0.340	0.336	-1.0%	0.337	-0.8%
Quaise Basin	3.1	0.325	0.322	-0.9%	0.323	-0.7%
East Polpis Harbor	**4**	**0.361**	**0.356**	**-1.5%**	**0.358**	**-1.0%**
West Polpis Harbor	4.1	0.371	0.365	-1.6%	0.367	-1.0%
Abrams Point	5	0.296	0.294	-0.5%	0.295	-0.4%
Monomoy	6	0.291	0.289	-0.7%	0.289	-0.7%
Mooring Area	7	0.285	0.284	-0.4%	0.284	-0.4%

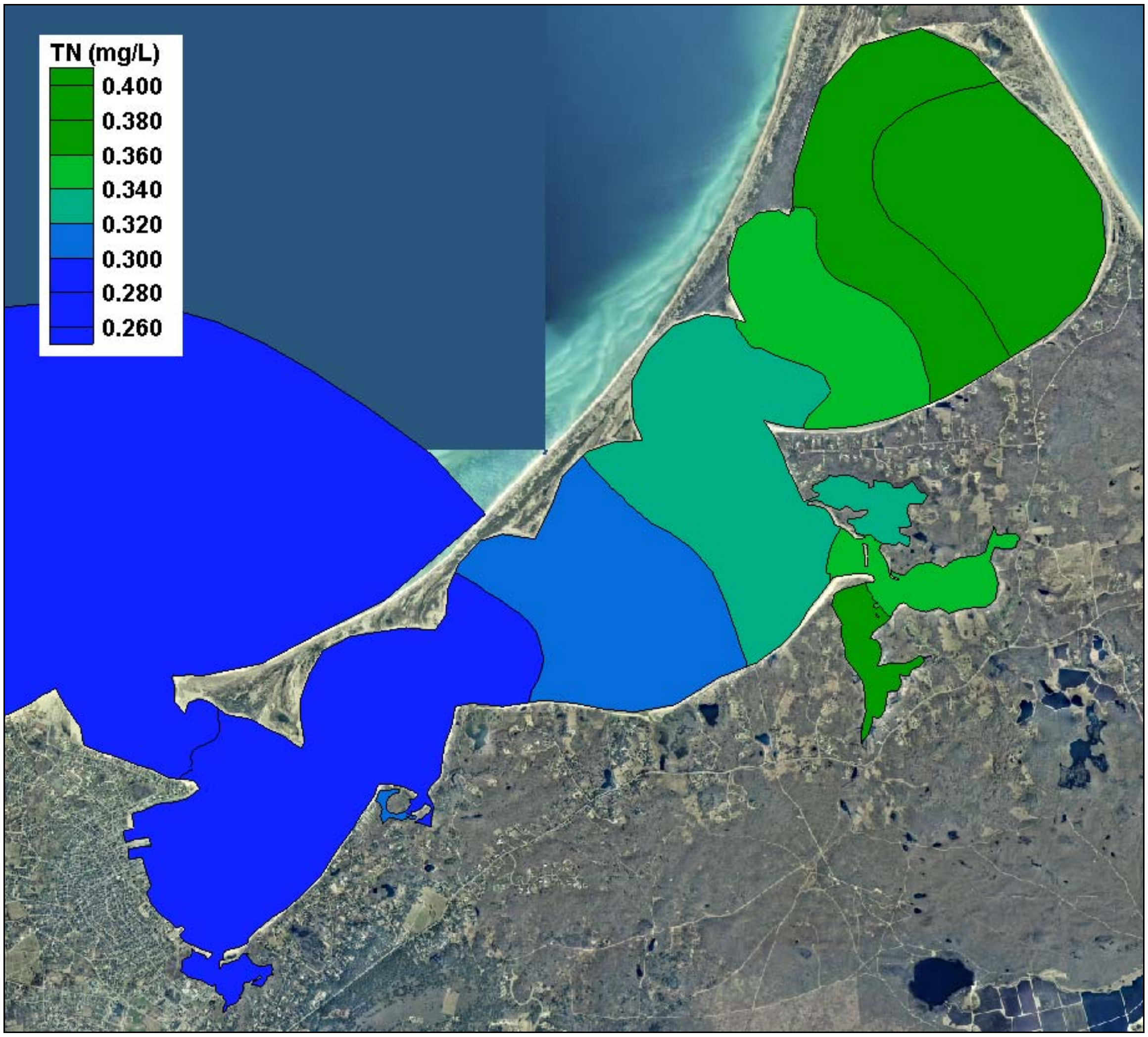

Figure VIII-1. Contour plot of modeled total nitrogen concentrations (mg/L) in the Nantucket Harbor system, for threshold "A" loading conditions.

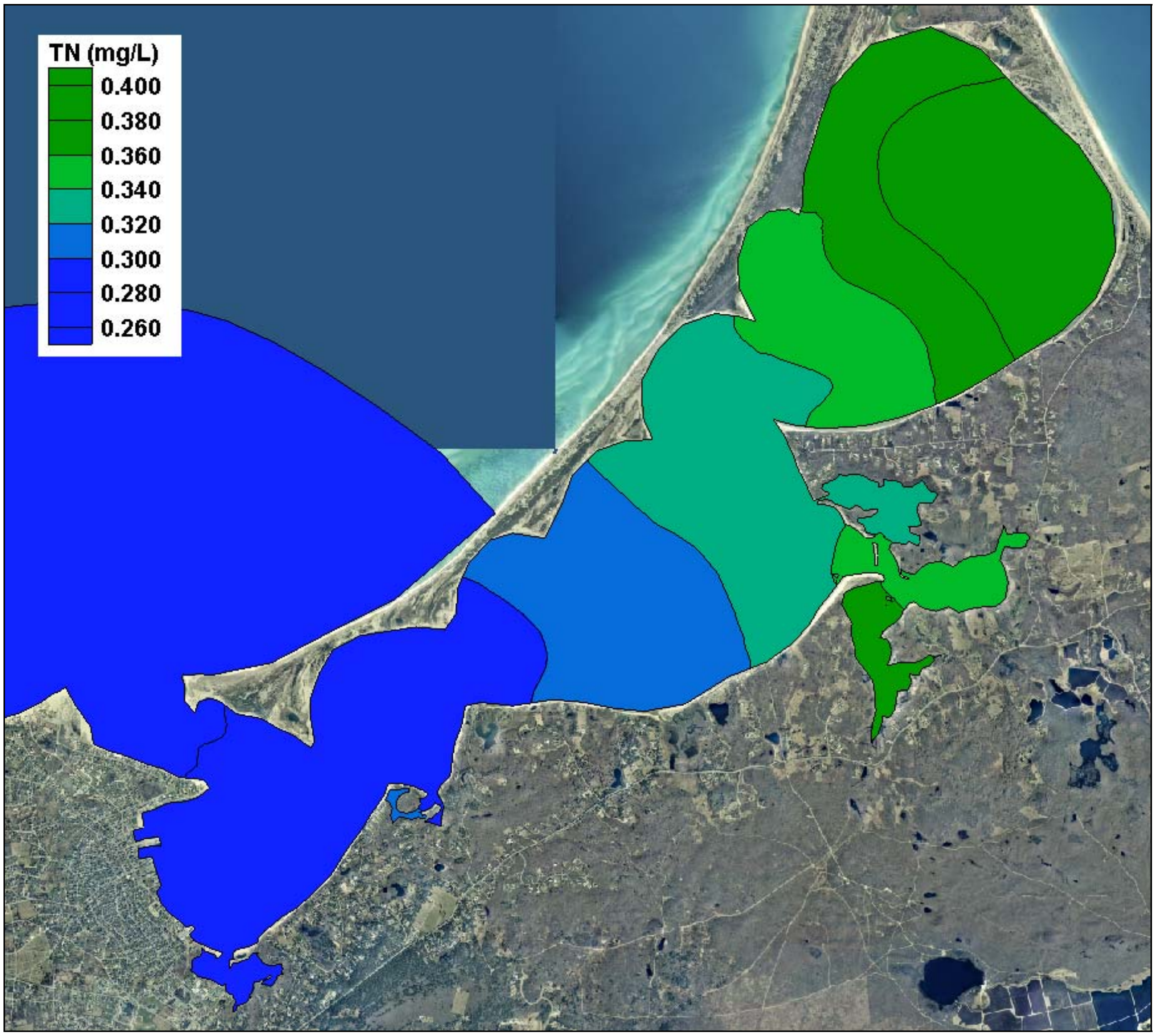

Figure VIII-2. Contour plot of modeled total nitrogen concentrations (mg/L) in the Nantucket Harbor system, for threshold “B” loading conditions.